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ABSTRACT

It is increasingly demanded that our academic institutions, having been the primary source of the material structuring our civilization, also be the vehicle for finding solutions for its ills. Society is pressuring the university to establish multidisciplinary programs as the most suitable mechanism for meeting these demands. This will require drastic reorganization in the structure and methodology of the university. The tightly structured, vertically oriented disciplines must be loosened to allow for horizontal diffusion of knowledge. The study of man and his environment, in particular, and the social sciences, in general, demand a drastic revision of curricula. A thorough investigation must be begun into the relations between academic offerings and social needs. (AF)

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1. *The Interdisciplinary Nature of Knowledge.*

It takes little scratching below the surface of any academic discipline to note its interdisciplinary development. With the possible exception of pure mathematics, all the sciences are crossbred academically. This heterozygosity among the sciences exists to varying degrees and depends largely where, within the discipline, the discussion focuses. The physicist, in his preoccupation with the nature of atomic bonding, finds himself associated intuitively with the chemist and biologist. Indeed, we have had interdisciplinary programs as biophysics, chemical physics, medical physics, etc., for some time. Even the course work now overlaps: thermodynamics is taught in physics, chemistry, and to a lesser extent, biology. The same is true of quantum mechanics. Similarly, our social sciences are now so intertwined that they are distinguishable only at the maximum of some kind of dispersion curve of pertinent knowledge. It is difficult to distinguish between some aspects of sociology and social-community psychology.

The examples above may be thought of as contiguous, with unestablished but well-recognized interfaces. However, we are all aware of seemingly unrelated academic unions, e.g., of law with the various professions, as medicine, patents, and, more recently

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with engineering, etc. Then what is new, and why the sudden concern? The answer would appear to be in the approaching crises for human existence, the clairvoyance offered students whose minds are not cluttered with experience, and the narrowness of contemporary academic training in terms of human requirements for planned survival.

It is conceivable that any, or many, of our institutions—academic, governmental, etc., could survive in a dying or ravaged civilization. Indeed, the monasteries in the Medieval Ages are stark reminders of such a condition. But there is increasing demand that our academic institutions, having been the primary source of the material structuring of civilization, also be the vehicle for the analysis and delineation of solutions for its ills.

No action, social or physical, is without its reaction. Granted, then, that the University must play a role in problem-solving within the society it affects, how does this affect the operation of the University and especially, from our point of view, graduate education?

2. *Will Multidisciplinary (M-D) Programs Require University Restructuring?*

Interestingly, the demand for m-d programs arises primarily from sources external to the University. Those within it are generally bound by the web of their own educational processes to operate within the now-traditional educational molds and generally view solutions to m-d problems as requiring the cooperation of individuals each trained in a unique discipline. A ploy used by

some is the double major, but unless some lessening of the normal academic rigors is allowed, this path is usually impossible, as the requirements of a single discipline are ipso facto sufficient to test the student to his limits. The dilution of single disciplinary demands to allow for double majors results in scholastic deficiencies which may require subsequent decades of efforts to strengthen, while the scholar himself is cast simultaneously in the role of an orphan, neither department claiming him for its own. Indeed, survival frequently results solely from the fortunate tradition of strong personal relations between the major professor(s) and the student, as well as the subsequent efforts of the scholar to choose a suitable academic pathway and determinedly, purposively, remove his deficiencies.

What, then, can one say concerning the bait dangled before Universities by the Federal Government in the form of monetary support for graduate programs in a specific resource, e.g., water? No one will doubt the need for clear understanding of the critical role of this compound in our daily lives and in any considerations of human survival. But even a casual examination of the scope of the proposed program shows it to have a complexity far beyond the capabilities of our educational systems as now constituted. An intelligent familiarity with the role of water as a natural resource involves familiarity with aspects of chemical engineering, law, economics, and sociology, as the very minimum. It is impossible in our present structure for any single individual

to attain the level of academic sophistication for a doctorate in all these disciplines simultaneously; a doctorate in a natural resource must, at the present, engage in dilettantism. Integrity requires that degrees granted in this area be distinguished from those given in the usual disciplines. In one case, we are cutting the cake vertically, scholarship measured as a function of increasing depth of the slice; in the other, the cut is horizontal, removing, in general, only the frosting. There is nothing wrong with frosting; the young, especially, dote on it. But just as the frosting alone will not tell much about the cake beneath it, so multidisciplinary studies may well neglect the substance of knowledge.

The very existence of multidisciplinary areas in the sciences is evidence that our tightly-structured vertically-oriented disciplines can be loosened sufficiently to allow for horizontal diffusion of knowledge. Few know this better than the biologist, who has seen his area grow, in my lifetime, from an almost completely descriptive one, where only human physiology had the beginnings of quantitative aspects, to today's arena involving, at the populational levels, the most sophisticated aspects of applied mathematics and, at the subcellular levels, combinations of physics, chemistry, and mathematics which, not too long ago, were considered the sacred domains of those disciplines alone. Analytically, the development in biology resulted not from the increasing sophistication of the biologist, but from the

"spill-over" of physicists and chemists (along with some of their curriculum) into biology. For example, in physics, the kind of physical optics common twenty years ago, is given scant shrift. The physics department course in physical optics is now given in terms of scatter theory, with a level of sophistication in mathematics beyond the present-day biochemist. The latter, utilizing physical optics routinely, must now teach physical optics in his own--frequently a biology--department. (The chemists have profited both ways, from their adaptation to the discipline of physics, and from their incursion into, and increasing domination of, biology.) But it is precisely this spill-over, both of curriculum and of individuals, which forms the basis for horizontal diffusion. Indeed, this is now here more obvious than in biology itself. In biochemistry, for example, the preoccupation, a third of a century ago, with the synthesis and requirements of essential amino acids and vitamins has given rise to the virtually separate discipline of nutrition; the many lectures on pH, its meaning and measurement in physical and biological systems, are now given only passing comment, and the students are referred to texts for detail. The biologist of that time was content in his mathematical training with an operational knowledge of calculus. The minimum now is differential equations, and it is easy to predict that, apart from the practical knowledge of computers as a tool, the future biologist shall need training in matrix theory, tensor calculus, and integro-differential equations.

The biological bases for much of social malignancy, the chemical bases required to resolve many technological problems of society, the physics bases of much of our industrial and material development, forces an interdigitation of the social and natural sciences; but the educational cost arising from the limited time for human education, cannot be neglected. We shall return to this point. Further, the social sciences introduce a completely new parameter into the properties of the system, namely, the philosophy of determining and ordering values; but again, we shall return to this later.

The question, still unanswered directly, is whether the University can restructure its educational system to provide a multi-disciplinary mode. And the answer is yes, if it is willing to undergo a drastic reorganization in its own structure and methodology. The problem is akin to that of the comparison of different cultures. It is well known that the logic of the linguistics of the language of American Indians (any of the separate main branches) is as different from Indo-European based languages as is a counting system involving the decadal, as compared to the binary bases. Just as there may be a theoretical infinity of cultures in our society, so there are an infinity of ways to slice the academic cake.

Let us take a horizontal slice as an example, and ascertain what is involved. Suppose that we consider the slice called "Transportation". A student comes to us and states that he wishes to do his doctorate in this field. Our immediate response is to refine the request into our accustomed vertical academic mold.

We ask, "What aspect of Transportation, economics, engineering, mathematics, etc.?" Until the student's mind is deformed from his relatively unstructured "liberal arts" background, he will undoubtedly have been thinking of a variety of aspects: of the changing modes of transportation, of his particular problems in getting to and from the university, of the parameters introduced by interplanetary transportation, of the relation between city development and various modes of transportation. And what do we do to this imagination? We tie it to a vertical discipline. If the student has been forced to reply to our vertical restriction by the phrase, "I do not know--Economics, I guess", then he is assigned to a specific problem, e.g., the relation between railroad rates and the I.C.C., a topic rather less lustrous than his dreams.

Obviously, the horizontal slice for Transportation as an area of scholarship is as intriguing as any of our present disciplines. There are most exciting facets: the legal; the engineering; the interaction with cities, states and governments; the relation to pollution; planning, priorities and funding. Unfortunately, even our manner of stating the problem tends to force us into the old ways of thinking. The curriculum for a major in Transportation could--and should--have an undergraduate, as well as a graduate aspect, where a dissection of the various aspects results in a sifted and graded dispersion. One would hope that in this rethinking, a preconceived vertical structure could be completely avoided. Thus one might have an introductory course in

the STRUCTURE of a modern (or primitive) Transportation System. There could be another on "Transportation and the FORM of city development". In both cases the word in capital letters is intended to indicate the point of view of the course. One might add, as a third, KINETICS, etc. The general notion is that if one wishes to take a horizontal approach in our University curriculum, it can be done, but it requires drastic alterations, so that presently constituted departments would be meaningless, as would be most of our vertical academic molds.

Such a revised horizontal curriculum would have both the rigor and sophistication of the present vertical curriculum. The degrees awarded would be fully equivalent both in intent and scope as those presently given. There would be no need for equivocation or pleas for leniency.

A thorny question is whether the two systems are compatible. In all probability an answer to this question exists, but it must be analyzed in a quantitative manner. Until individuals are trained according to the horizontal approach, the most practical mechanism is intercalation or interdigitation. One mode of this is the teaching approach used in some medical schools, where, to study the body as an "organ or tissue", the several vistas represented by the various vertical disciplines (pathology, anatomy, biochemistry, etc.) are presented by different staff members, each trained in one of those disciplines. For a particular organ, e.g., the heart, there will be lectures on

blood, biochemistry, muscle structure, rheology, pathology, etc., all relating to the heart. The student is then left to do the integration, having viewed the organ from the several vantages. Interestingly enough, in post-doctoral studies, i.e., in residencies, the horizontal approach becomes standard, so that medics, in "specializing" become indoctrinated (!) in all aspects, e.g., of "internal medicine", "eye, ear, nose, and throat", etc. The presumption obviously is that by the time a medic reaches his residency, his training is sufficiently broad to allow him to correlate various vertical disciplines into a broad horizontal one.

3. *On the Uniqueness of the Horizontal Structure in the Social Sciences.*

We return now to the two points noted earlier, but postponed for further discussion: a) the limits imposed by time on the formal educational process, and b) the evolutionary uniqueness of the human being in devising models for progress. Consider the latter first. There is a uniqueness in those disciplines involving human endeavor. In all other disciplines we strive to bring order into the miasma of ignorance. We proceed from the assumption that our inquiries require only an ascertaining of facts and an ordering of the facts into models or theories which may be tested in one manner or another. This is implicit in the natural sciences. However, the study of man cannot avoid introducing the parameters of possible large-scale *purposeful* environmental and genetic changes, so that both the rate and

direction of evolution may be affected. Thus *the goals of human endeavor become a component of human studies.* While it is possible, for example, to study the past development of transportation in a reasonably precise manner, devising models relating past rates of urban growth with railroad construction, it is *not* possible to prepare models of *future* transportation without assumptions concerning the structure of cities, and plans for the latter vary considerably. Equally difficult problems will be raised when we learn how to modify specific genes, the evolutionary consequences of which will be unpredictable. Even in as restricted an area as the immediate alteration of a local environment (e.g., the proposed filling of San Francisco Bay) there would be profound effects, both physical (i.e., meteorological) and social, with global reverberations. In short, while there are examples of highly organized, lengthily-evolved animal societies, e.g., ants and bees, we have no knowledge of the evolutionary bases of their development nor have any past forms of life been able, as far as we can ascertain, to effect as broad a change in the environment as humans. Ants and bees make a local environment, but man can change, if he will, the entire earth. Indeed, by his pollution, he is doing it whether he wills or not.

As a consequence, we are without models for the development of human affairs, and academic multidisciplinary studies involving this parameter can operate only in the light

afforded by history and in the aspirations of mankind. Any non-historical models we construct will be without precedence. We shall have no knowledge of their effectiveness, now will we be able to ascertain their utility except by empiricism, i.e., by testing. Strategies presumably will be devised which cause the least social discomfort, and these strategies will require considerations of rates, quantities, and directions of change, the consequences of which cannot be foreseen.

Our last point concerns our temporal limitations. There are constraints in time which set bounds for higher education. We must devise m-d curricula which satisfy the rigors and standards for a level of scholarship which molds human endeavor and, at the same time,develop individuals who can serve as physicians to the ills of society. A Ph.D. in Urbanology will require knowledge in the engineering, social, legal, historical, and architectural interrelations of ancient and modern cities. He will have to have thorough knowledge of the methodologies for optimization of matrices, of the sociological consequences of diverse forms of density distribution of human habitats, and of the psychology of enforced leisure.

Programs of this type will require drastic revisions in our curricula if the studies are to be completed in the usual time allocated to academic studies--and not to be thought of as lifetime affairs or performed only by cooperative efforts of several individuals trained in vertical disciplines. It is conceivable that a wholly new rationale in curricula will be required.

It is time to begin a thorough investigation into the relations between our academic offerings and our social needs.